

MARYLAND'S GREEN INFRASTRUCTURE—USING LANDSCAPE ASSESSMENT TOOLS TO IDENTIFY A REGIONAL CONSERVATION STRATEGY

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Abstract. Maryland is growing at a very rapid pace. Compounding the problems associated with rapid growth is the scattered pattern of development that consumes an excessive amount of land and fragments the landscape. As land use changes, wildlife habitat and migration corridors are lost and normal ecosystem functions are disturbed or destroyed. While land use planners and developers are attempting to minimize such impacts, they do not always know where key natural lands and corridors are situated. The Green Infrastructure Assessment (GIA) provides this information and can be used to identify a greenway network that will protect the most critical lands in the state before they are gone forever. Using GIS and principles of landscape ecology, the Maryland Department of Natural Resources is identifying an interconnected network of “hubs” and “corridors” that are now the focus of state and local agency deliberations and revisions. Elements of the network are being prioritized for conservation and restoration activities based on ecological parameters (e.g., sensitive species, important wetlands or riparian zones, etc.) and threat parameters (e.g., protection status, development pressure, etc.). The goal of GIA is to help identify an ecologically sound open space network, and ultimately, to incorporate the agreed upon network into state and local land conservation planning.

1. Introduction

1.1 MARYLAND'S CHANGING LANDSCAPE

The population and developed portions of Maryland have grown rapidly. Between 1790 and 1990, Maryland's population grew from 320,000 to 4,780,000 (RESI 1997). Maryland's population is projected to increase an additional 24.4% between 1995 and 2025 (RESI 1997). Developed land has increased even faster than the population. Between 1985 and 1990 alone, developed land use increased by 18.6%, to 373,000 ha (RESI 1997). This development has come primarily at the expense of agriculture and forest. Wildlife habitat and migration corridors are being lost, and normal ecosystem functions such as absorption of nutrients, recharging of water supplies, and replenishment of soil are being disturbed or destroyed. Water quality has been degraded in numerous streams and rivers. Many of Maryland's remaining wetlands have been altered by filling, drainage, impoundment, livestock grazing, logging, direct discharges of industrial wastes and municipal sewage, freshwater diversions, and non-point discharges such as urban and agricultural runoff (Tiner and Burke 1995).

The scattered pattern of modern development not only consumes an excessive amount of land, it fragments the landscape. Numerous studies have shown the

negative ecological effects of forest fragmentation in the landscape, including Harris (1984), Yahner (1988), Williams (1991), Hansen and Urban (1992), Donovan et al (1995), Robinson et al (1995), and Gibbs (1998). As forest areas are divided and isolated by roads and development, interior habitat decreases, human disturbance increases, opportunistic edge species replace interior species, and populations of many animals become too small to persist.

1.2 STUDY AREA

The Green Infrastructure assessment was carried out within the state of Maryland. Maryland ranges from the Atlantic Ocean to the Appalachian Mountains, spanning five physiographic regions (Coastal Plain, Piedmont, Blue Ridge, Ridge and Valley, and Appalachian Plateau). Each region is defined by unique geology and varying climate, and thus different assemblages of flora. Maryland is important geographically, at the southern extent of many northern plant and animal species, and at the northern extent of many southern plant and animal species (Williams 1991).

1.3 OBJECTIVES OF MARYLAND'S GREEN INFRASTRUCTURE ASSESSMENT

Maryland's Green Infrastructure Assessment (GIA) is a tool being developed to help identify and prioritize areas in Maryland for conservation and restoration. It uses Geographic Information Systems (GIS) technology to identify large, ecologically valuable areas (hubs) and a potential system of connecting corridors. These areas are further prioritized according to their relative ecological importance, as well as the potential risk of loss to development. Prioritization is done on two scales: by entire hub or corridor; and by individual grid cell (0.137 ha). Two tiers of hubs are identified: those of statewide significance, at least 2000 ac (809 ha); and smaller hubs, 500–2000 ac (202–809 ha), which may be of local concern. The "local" hubs would be linked by corridors to the statewide hub and corridor network. "Nodes" are patches of interior forest, wetlands, sensitive species areas, or protected areas along corridors. These serve as "stepping stones" for wildlife movement along corridors.

This paper discusses the approach used to delineate and prioritize the green infrastructure for land and ecosystem conservation initiatives.

2. Green Infrastructure Identification Methodology

2.1 SELECTION OF ECOLOGICAL COMPONENTS

Incorporating landscape ecology principles, we performed a coarse scale landscape analysis, striving to include a full range of ecosystem elements. The assess-

ment was limited to features with GIS data available statewide. The GIS data layers listed below were used in identification and prioritization of the Green Infrastructure. All data sets were projected to Maryland State Plane, NAD 1927, and converted to grids with a cell size of 0.34 acres.

- Land Cover (MRLC)
- NWI Wetlands
- Streams, Estuaries and Atlantic Ocean
- Elevation (30 and 90 m DEM)
- FEMA 100 Year Flood Plains
- Wetlands of Special State Concern
- Natural Heritage Areas
- Sensitive Species Review Areas
- Maryland Biological Stream Survey (MBSS) Living Resource Data
- Submerged Aquatic Vegetation (SAV)
- Protected Lands
- Roads
- Watershed Boundaries
- Natural Soils Groups
- State and County Boundaries
- Development Pressure
- Generalized County Zoning

2.2 HUB IDENTIFICATION

Hubs, or core areas, were defined as contiguous areas of major ecological importance, at least 2000 ac (809 ha) in size. These areas were identified by combining Wetlands of Special State Concern (WSSC), Sensitive Species Project Review Areas (SSPRA – including threatened and endangered species locations and other important natural areas), blocks of interior forest at least 500 contiguous acres (202 ha) plus a 500 ft (152 m) transition zone, unmodified wetlands at least 500 ac (202 ha) plus a 550 ft (168 m) upland buffer (from Brown et al. 1990), and existing protected lands (properties owned by Maryland DNR, federal lands managed for conservation or with large undeveloped areas, county lands managed for conservation, and private conservation lands). We defined interior forest as forest area preferred by species that require interior, isolated habitat (Harris 1984; Forman and Godron 1986), and the distance from forest edge to interior was based on observations of negative impacts on interior forest wildlife species (Bushman and Therres 1988, Brown et al. 1990). The threshold of 2000 ac was fairly arbitrary, based on visual inspection of map output for different sizes.

2.3 ASSESSING LANDSCAPE (HUB) LINKAGE POTENTIAL

Corridors in the Green Infrastructure are linear features linking hubs together, to allow animal (terrestrial, wetland, and/or aquatic) and seed movement between hubs, in the hope of maintaining viable and persistent metapopulations. The landscape between hubs was assessed for its linkage potential, identifying conduits and barriers to wildlife and seed movement. Preference was given to streams with wide riparian buffers and healthy aquatic communities (from Harris 1984, Forman and Godron 1986, Brown et al. 1990, and Forman 1995). Other good wildlife corridors included ridge lines, valleys, and forest. Urban areas were avoided.

A "corridor suitability" layer based on land cover, streams, riparian width, aquatic community condition, road, slope, and protected land "impedance" (the inverse of "suitability") to animal and seed movement was created. Impedance measures the degree to which the landscape parameter inhibits wildlife use and movement.

2.4 CORRIDOR IDENTIFICATION

Least-cost path analysis was used to determine the best ecological routes between core areas or hubs. The analysis resulted in the delineation of a pathway between core areas with the lowest cumulative resistance to wildlife movement. These included riparian, upland, and mixed connections between hubs.

The next step was to delineate corridors along the least-cost paths. Where corridors followed streams, streams were buffered 550 ft (168 m) on each side, giving 50 ft (15 m) of interior conditions and 500 ft (152 m) of transition to edge on either side. If the floodplain exceeded this distance, the corridor was defined by the 100-year floodplain according to FEMA, to a maximum of 1000 ft (305 m) from the pathway. Where corridors were not along streams, the least-cost path was buffered a distance of 550 ft (168 m). Figure 1 shows the resulting composite conceptual hub-corridor network.

2.5 NODES

"Nodes" were patches of interior forest (with a 500 ft transition zone), unmodified wetlands, sensitive species areas, or protected areas along corridors. These serve as "stepping stones" for wildlife movement along corridors. Only natural land cover within these areas was incorporated within nodes.

2.6 HUBS OF LOCAL SIGNIFICANCE

A second tier of the green infrastructure comprises smaller hubs (500–2000 ac) which may be of local or regional concern. Ultimately, these could be linked by corridors to the hub and corridor network of statewide significance.

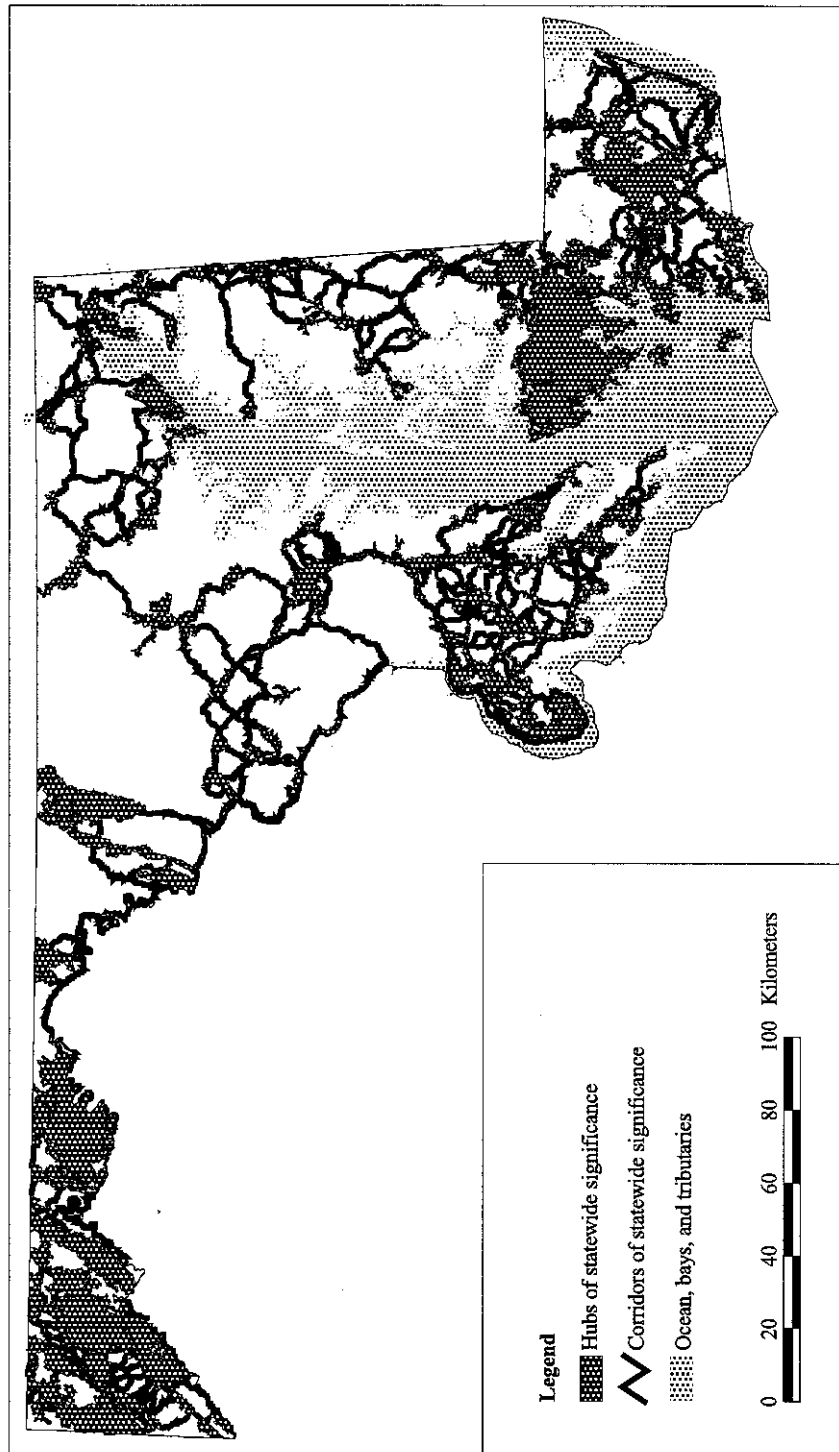


Figure 1. Potential landscape hubs and corridors in Maryland.

3. Green Infrastructure Prioritization Methodology

3.1 HUB AND CORRIDOR PRIORITIZATION FOR PROTECTION

Hubs and corridors were ranked according to their ecological importance and their potential risk of loss to development. Hubs of statewide significance and connecting corridors were ranked within each physiographic region of Maryland. For purposes of deriving discreet analytical units, hubs were separated by major roads and/or intervening development, mining, or agriculture. We considered only resultant areas at least 100 ac. Within each region, hubs and corridors were ranked from highest to lowest for a variety of ecological and risk parameters, as well as combinations of these.

3.1.1 *Ecological Ranking*

Within each physiographic region, hubs and corridors were ranked from best to worst for the parameters listed below.

Hub Parameters

- Proportion of natural cover
- Area of interior forest
- Area of unmodified NWI wetlands
- Area of Wetlands of Special State Concern
- Area of Sensitive Species Project Review Areas
- Area of Natural Heritage Areas
- Slope
- Number of stream sources and junctions
- Length of headwater streams within interior forest
- Number of interstate connections
- Road density
- Land cover surrounding hub
- Patch shape

Corridor Parameters

- Ecological ranking of hubs connected by corridor
- Versatility of connection (terrestrial/aquatic/wetland)
- Corridor length
- Node area along corridor
- Number of corridor breaks
- Primary road crossings
- Secondary road crossings
- Rail crossings
- Proportion of natural cover
- Land cover surrounding corridor

The above rankings were multiplied by a parameter importance weighting (High, Medium, or Low), and added together for each hub or corridor, producing a final nonparametric rank from highest to lowest relative "ecological importance". Parameters were chosen and weighted according to feedback from biologists and natural resource managers. All hubs and corridors of statewide significance were

considered ecologically important, but the relative rankings can be used to prioritize conservation efforts.

Using spreadsheets, hubs and corridors were ranked from highest to lowest for each parameter above, except for the number of corridor breaks, road and rail crossings, which ranked from lowest to highest. For example, the hub with the most interior forest would have a ranking of 1 for that parameter, whereas the corridor with the most breaks might have a ranking of 100 for the parameter. We multiplied the ranking by the parameter's importance weighting (5 for high importance, 2 for medium importance, and 1 for low importance). Then, we added these together, using this linear combination to rank hubs or corridors from best (lowest) to worst (highest) combined score. Figure 2 shows the resulting ecological ranking of hubs in the Piedmont physiographic region.

A nonparametric ranking was selected because we lacked information needed to evaluate thresholds (e.g., what density of stream nodes is desirable?) or to standardize parameters (they were in different units).

3.1.2 *Risk of development ranking*

Within each physiographic region, hubs and corridors were ranked from highest to lowest for each of the parameters identified below.

- Area not protected by regulatory mechanisms
- Development pressure
- County zoning

Regulatory mechanisms included public ownership, privately owned conservation lands, conservation easements, wetland delineation, SSPRA, and steep slopes. Development pressure was obtained from the Maryland Office of Planning, and represents the acres of developable land divided by the number of projected dwelling units for a particular planning area (Rosen et al. 1998). It was calculated using county zoning, 1994 land use data, and either individual county small area forecasts for transportation analysis zones or county-wide forecasts allocated to election districts, as available (Rosen et al. 1998). We converted this data to a value between 0 and 10, and compared the mean within each hub. The three parameter rankings were multiplied by an importance weighting (High, Medium, or Low), and added together for each hub or corridor, producing a final nonparametric rank from highest to lowest relative risk of development. Figure 3 shows the resulting ranking of hubs in the Piedmont for threat or risk of development.

3.2 CELL-BASED PRIORITIZATION FOR PROTECTION

Prioritization of the Green Infrastructure was done on two scales: by entire hub or corridor, as discussed above; and by individual grid cell (approximately a third of

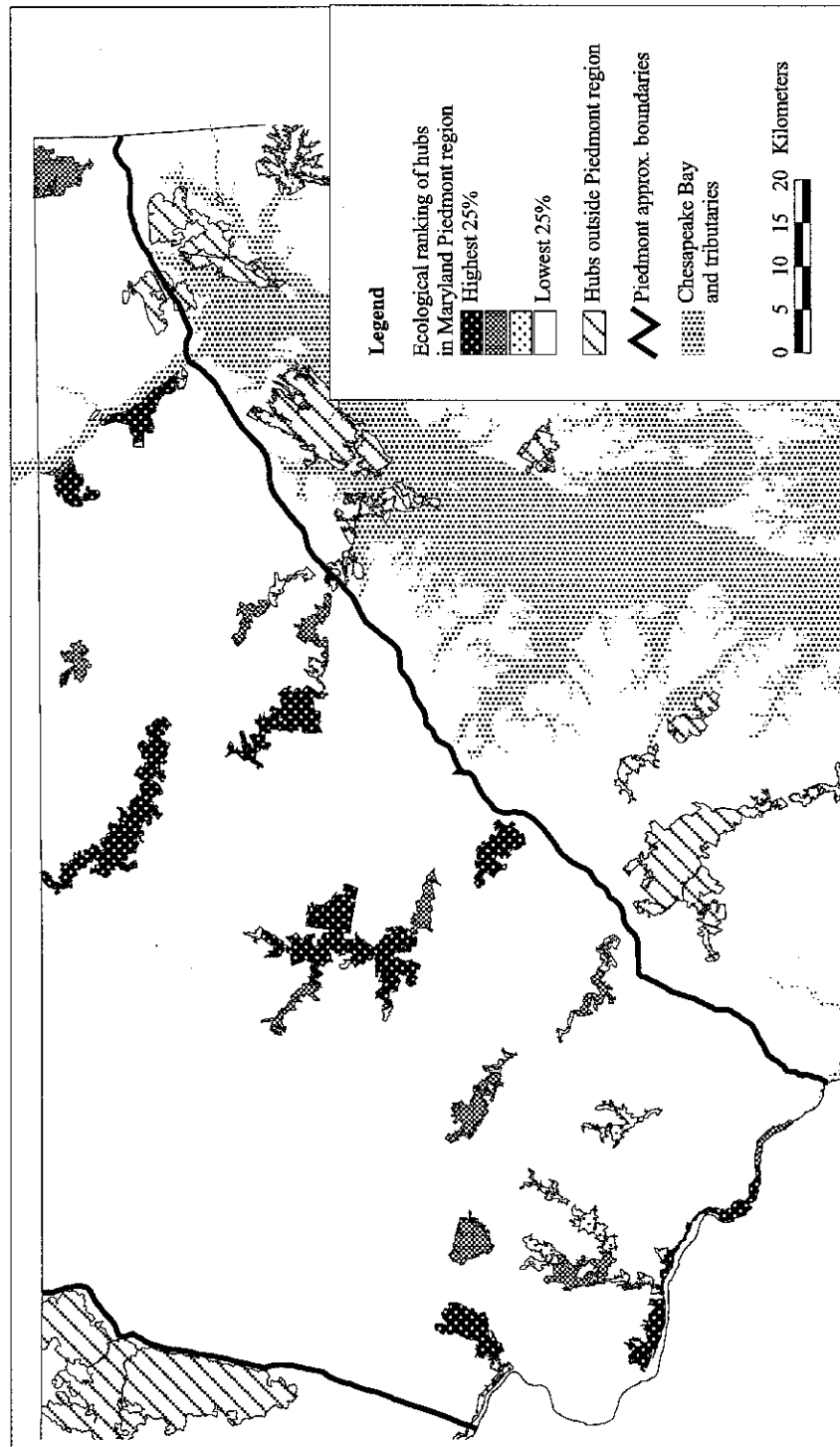


Figure 2. Ecological ranking of landscape hubs in Maryland Piedmont region.

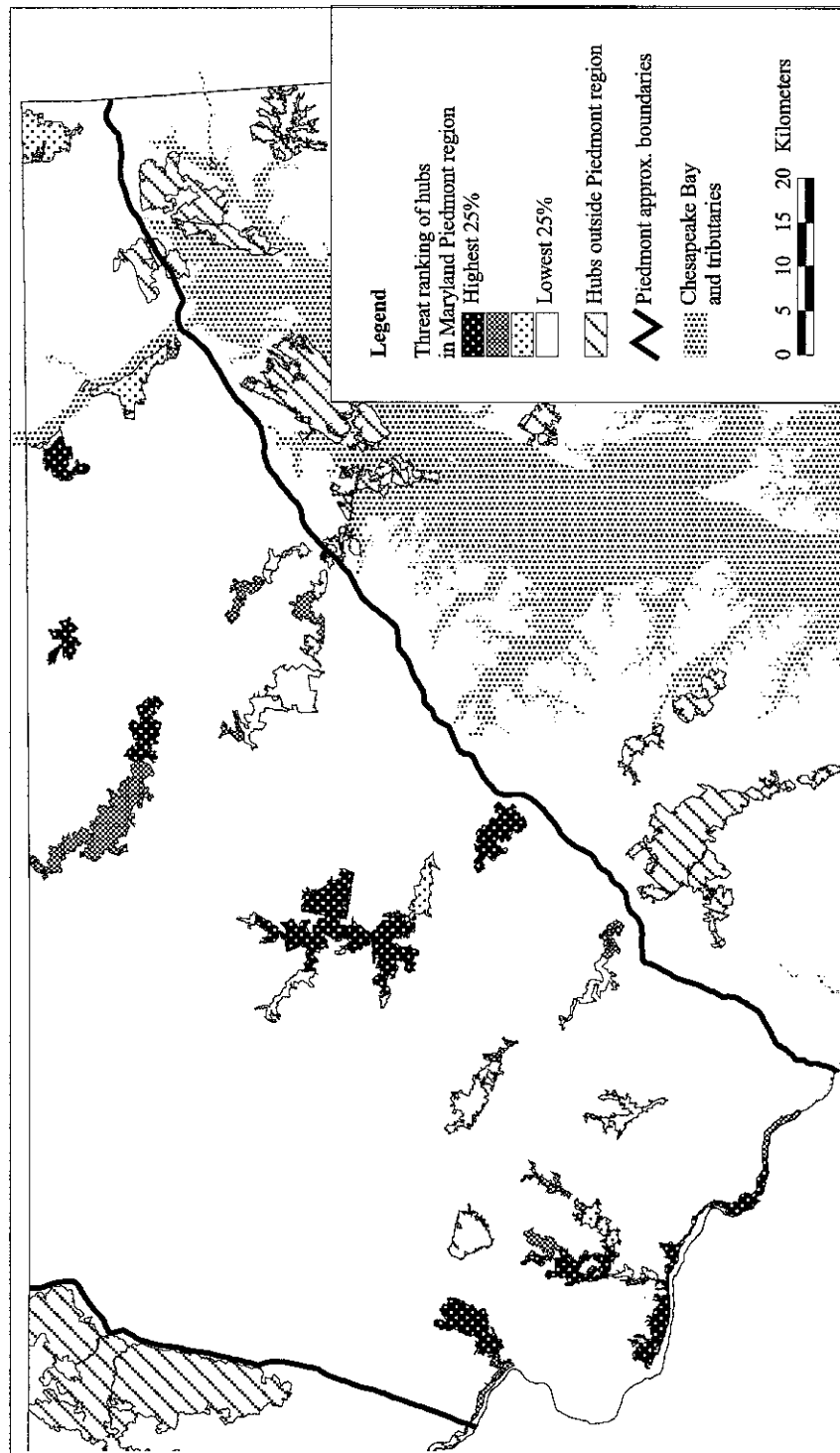


Figure 3. Threat of development ranking of landscape hubs in Maryland Piedmont region.

an acre). The latter, finer, scale allowed a more detailed analysis for site prioritization within hubs.

3.2.1 *Ecological ranking*

To help prioritize areas within the Green Infrastructure, individual cells were ranked according to the parameters identified below.

- Land cover type
- Slope
- Proximity to Wetlands of Special State Concern
- Presence of interior forest
- Sensitive Species Project Review Areas
- Proximity to streams
- Biotic integrity of streams
- Remoteness from roads
- Proximity to unmodified wetlands
- Wetland mitigation value
- Proximity to Natural Heritage Areas
- Proximity to Submerged Aquatic Vegetation
- Proximity to first-order streams
- Proximity to stream sources and junctions

The parameters above were scaled between 0 and 10, and combined linearly. The sum was grouped into five classes by equal-area distribution.

3.2.2 *Risk of development ranking*

To help prioritize areas within the Green Infrastructure, individual cells were ranked based on their vulnerability to development. This combined regulatory mechanisms, weighted by their restrictiveness, multiplied by a linear combination of development pressure, zoning, and distance from roads. The latter layers were scaled between 0 and 10, where 0 was considered low risk of development, and 10 was considered high risk of development, and weighted according to their relative importance (high, medium, or low). The final combination varied between 0 and 90. This was grouped into five classes by equal-interval distribution.

4. Green Infrastructure Assessment – Issues for the Future

The green infrastructure assessment methodology was developed, in part, to provide a consistent, scientifically-defensible approach for evaluating ecosystem conservation and restoration initiatives in Maryland. It specifically attempts to recognize: 1) the role of a given place as part of a larger interconnected ecological system, 2) the value of integrating multiple resource interests into a single frame-

work, 3) the importance of considering natural resource/ecosystem integrity in the context of existing and potential human impacts to the landscape 4) the importance of regional (i.e., inter-jurisdictional) coordination of local planning, and 5) the need for a regional element to a biodiversity conservation strategy. The green infrastructure will continue to be refined based on input on ecological significance and landscape risk to development from local governments and other organizations. Finally, an effort is underway to better integrate the assessment methodology with the Mid-Atlantic Gap Analysis Project (see Scott et al. 1993). As a result, the green infrastructure will be modified to incorporate additional biological diversity conservation information derived from GAP.

Based on feedback from scientists, further literature reviews, and comparing model output to maps and aerial photographs, the GIS model is currently undergoing several revisions. For example, the size thresholds for "state significant" and "locally significant" hubs are being replaced by ranking all potential conservation areas from the outset, and selecting the most important of these to prioritize and link with corridors, where appropriate. The parameters used to define core interior forest and wetland complexes have changed, and aquatic biodiversity core areas added. Size and proximity to other natural areas will be important ranking factors, so the network may not change greatly. Parameters for hub ranking and corridor suitability will be adjusted by comparing sample model output to knowledge of local biologists.

Among additional tasks, gaps within hubs and corridors are being prioritized for restoration efforts, according to their ecological benefits and reclamation ease. Impacted wetlands can also be targeted for remediation. Structures such as underpasses or bridges can facilitate wildlife movement where roadways and railways cross corridors and core areas. Similarly, stream blockages can be identified for fish ladders, bypasses, or other structures.

Implementation of the Green Infrastructure Assessment should be preceded by photographic and field assessment. Because of limitations in data resolution, maps of model output are only meaningful at a 1:100,000 scale or smaller. Acquisition dates varied between 1980 and 1997, mostly between 1991–7. For site-specific planning, maps should be photo and field verified, and boundaries defined using aerial photographs and property maps. Figure 4 depicts an example of delineating a randomly sampled riparian corridor using aerial photography.

Field assessment will also allow discrimination between mature forest and successional or regenerating forest, or between natural forest and pine plantations. Data from vegetation and wildlife surveys can be combined non-parametrically, as in GIS ranking of hubs and corridors; or standardized, weighted, and combined linearly. Areas ranking high in the landscape-scale GIS assessment, but low on the ground, should be given lower priority for conservation than areas ranking high in both categories.

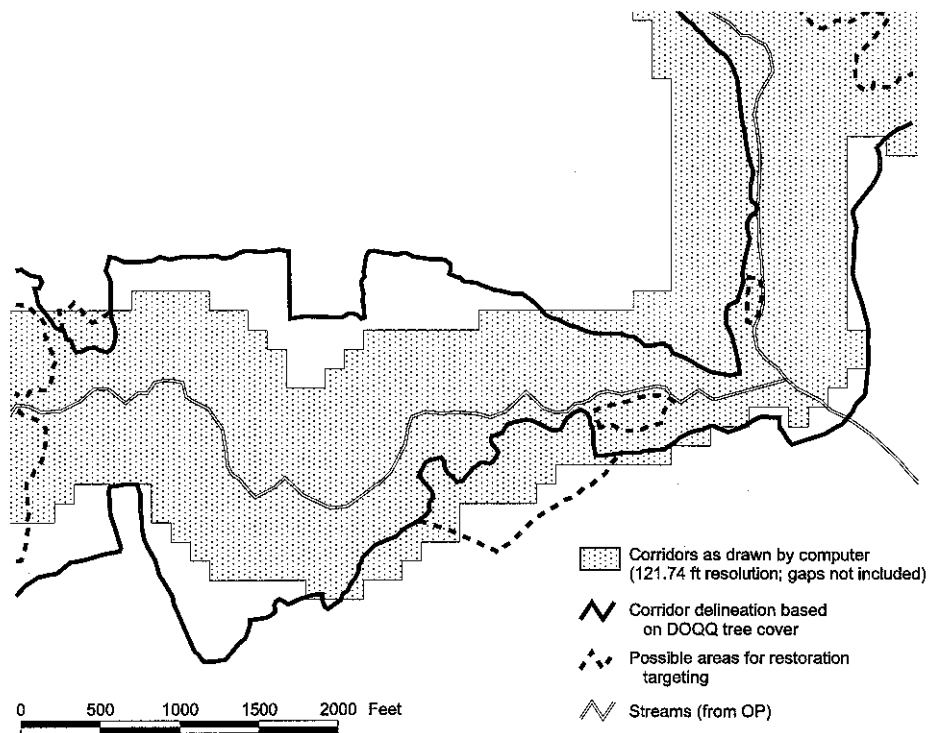


Figure 4. Riparian corridor delineation, comparing medium-scale GIS assessment to large-scale DOQQ photography.

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